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tion practices are adopted. On the lands highly suited to rice production, rice is the dominant crop regardless of water costs. The high elasticities show that rainfed dryland production is very competitive except on a relatively small acreage highly suited to rice production. At low water costs, soybean irrigation could expand significantly.

"Planning for Wildlife Enhancement in Federal Irrigation Projects." Jeffrey E. Hanson and Scott C. Matulich (Washington State University)

A bioeconomic planning effort aimed at enhancing potential environmental changes resulting from irrigation development in the East High region of the Columbia Basin Project, Washington, is presented. A cost effectiveness framework is employed to develop a frontier of least cost wildlife enhancement plans compatible with anticipated irrigation impacts. Planning is advocated so as to convert short-run positive spillovers of irrigation development into long-term, sustained social benefits. Contributions of environmental enhancement planning to the decision making process are discussed. Planning is advocated as an equally important, but often overlooked, mandate of federal mitigation legislation.

"Distributional Welfare Implications of Water Subsidy." Linda S. Calvin, William E. Foster, Grace M. Johns and Patricia Rottschaefer (University of California)

The distributional welfare implications of a subsidy on irrigation water for California rice producers are analyzed. A more general equilibrium approach than that used in previous studies is taken to determine the effects of subsidy on consumers, subsidized producers, and unsubsidized producers. The two important policy conclusions of the results are: 1) unsubsidized producers bear part of the cost of a subsidy through lower prices, and 2) consumers (taxpayers) may gain by sponsoring increased production through a selective subsidy.

"Salinity Regulation and Irrigation Development: Welfare and Conservation Implications." Douglas R. Franklin and James J. Jacobs (University of Wyoming)

The impacts of increased agricultural and energy development in Wyoming's Green River Drainage were analyzed to determine the possible "cost" to the state to meet an EPA imposed salinity regulation. The analysis incorporates a damage cost charged to "producers" for increased salinity in the river basin based on return flow, consumptive use and water conservation management strategies. The results indicated, as do other studies, that salinity is a major constraint for development of Colorado River Basin water.

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When water use problems cannot be effectively solved by individual or local initiative, the public sector has acted to achieve a balance. In most cases, government management policies have included imposition of regulations. For example, in the Upper Colorado Basin as anticipated water use increases, water quality questions arise regarding downstream water use (Padungchai, 1980; Wyoming State Engineer, 1977b; and Hyatt, 1970). The government policy includes among others a salinity standard administered by the Environmental Protection Agency (EPA). While salinity does not impose much damage to water users in the Upper Basin, significant damages are imposed on water users in the Lower Basin in the form of crop damage, decreased soil productivity, high treatment costs, pipe corrosion and greater use of detergents and chemicals.

An agreement between Upper Basin States and EPA in 1974, requires that salinity not exceed 1972 levels at Lee's Ferry, Arizona. In 1976, EPA imposed salinity standards below Hoover Dam, Parker Dam and Imperial Dam in the Lower Basin. Anticipated energy and agricultural development in the Upper Colorado River Basin states could be affected by the salinity standards imposed by the EPA. For example, surface mining operations for coal, oil shale and tar sands will expose new geologic materials to the atmosphere and could contribute additional salt to surface and subsurface runoff. Also, additional withdrawals of surface water to meet expanding energy and agriculture needs will increase the salt concentration of remaining river flows. Thus, the appropriation of presently unused surface water for energy, agricultural and domestic purposes could increase the salinity for downstream users.

This paper focuses on the welfare implications associated with increased agricultural and energy development within the Green River drainage basin, an area of rapid energy development in Wyoming, both with and without EPA salinity regulations. A secondary objective of this paper is to estimate the impact of alternative water conservation and salinity management practices given the increased development in the basin. The paper is organized in the following manner. The next section discusses the water resources, practices and quality issues of the Green River Basin. The analytic model used in the analysis is discussed in section three and the results, discussion and conclusions are presented in section four.

WATER RESOURCES

Development of Wyoming's energy resources may require substantial amounts of water. The question of whether there are adequate water resources to sustain anticipated energy development and its associated economic activities has produced several water inventory studies. Studies that include or pertain to the Green River Basin are the annual reports by the Upper Colorado River Commission, U.S. Department of the Interior (1974), the U.S. Water Resources Council (1971), and the Wyoming State Engineer (1977a and b). The 1977 report by Wyoming concluded that from 340,000 to 580,000 acre-feet of water per year is available to meet future needs in the Green River Basin. This is also consistent with other water inventory reports for the Upper Colorado River Basin, notably, Narayanan et al. (1979) and Hyatt (1970).

The actual flow of the Colorado River is less than the flow estimated for the Colorado River Compact made between Wyoming, Colorado, New Mexico, Utah, Arizona, Nevada and California on November 24, 1922. Article III of the Colorado River Compact apportioned in perpetuity the exclusive beneficial consumptive use of 7,500,000 acre-feet of water per year to the Upper and

Lower Basin states. Under Article III of the Upper Colorado River Basin Compact signed on October 11, 1948, Wyoming's share is 14 percent or 1,043,000 acre-feet of water per year after Arizona's entitlement of 50,000 acre-feet. However, the above estimated flow of the Colorado River was overly optimistic. The Upper Colorado River Commission estimates the annual virgin flow is 14,000,000 acre-feet. To meet the obligations of 7,500,000 acre-feet per year to the Lower Basin states, an additional 750,000 acre-feet delivery to Mexico under Section III of the Mexican Treaty signed on February 3, 1944, and Arizona's entitlement, Wyoming's share of water under the Upper Colorado River Basin Compact would be 798,000 acre-feet. Under Article III of the Colorado River Compact, all reallocation of water due to an overestimation of flow is to be shared by the Upper Basin states. This places a greater burden on Wyoming and other Upper Basin states to meet their obligations in water short years.

Because the water available for allocation established under the Colorado River Compact is less than the flow estimated in the compact, the Upper Basin states have less than their share of the annual consumptive use of 7,500,000 acre-feet allocated in the compact. As indicated by the State of Wyoming's 1977 report, Narayanan et al. (1979), Upper Colorado River Commission and the U.S. Bureau of Reclamation, considerably less water is available for consumptive use in the Green River Basin of Wyoming. The Upper Colorado River Basin Commission keeps fairly accurate data on the "virgin" or natural flows of the Colorado River and thus, the allotments to each state.

The base figure used in this study is the U.S. Water Resources Council's long-term discharge of 14,994,200 acre-feet per year for the Colorado River. Wyoming's share would be 864,000 acre-feet per year after evaporation losses. With 1975 depletions in Wyoming amounting to 409,200 acre-feet, water available to meet Wyoming's future needs is 454,800 acre-feet on an annual basis.

Water Use Practices

Irrigation is the largest consumptive use of water in the Green River Basin. Over 250,000 acre-feet of water are consumed annually by irrigation. This accounts for over 60 percent of the total consumptive use in the basin. Due to the arid climate, irrigation is an essential component of crop production. Over 336,000 acres of land were under irrigation in 1975. Most of the cropland is in hay, pasture and small grains. There is a potential for increased yields on 205,000 acres by better and more intensified management (State of Wyoming, 1977b).

Coal mining, steam electric power generation plants, oil and gas industry and trona mining are the major industrial users of water in the basin. Currently, 10 percent of the consumptive use, or about 41,000 acre feet, is by these industries (State of Wyoming, 1977b). Projected energy development in coal, oil and gas, trona, uranium and oil shale by the year 2000 will bring about large increases in the consumptive use of water. Upwards of five to eight fold increases in consumptive use by the energy sector may be needed to meet all projected developments. Such requirements would still be within the current water availability.

Reservoir evaporation depletions, fish and wildlife, recreation, municipal and domestic consumption, inter-basin transfers and other depletions such as Wyoming's share of the Colorado River Storage Project (CRSP) evaporation, combine to account for approximately 120,000 acre-feet per year--less than 30 percent of the total consumptive use in the Green River Basin. Any increase in energy production will also tend to increase municipal water demand. Yet, any salvage of water through reduction of reservoir evaporation or phreatophyte transpiration will decrease the basin's overall depletion thereby allowing for more water for other beneficial uses.

Water Conservation Issues

Water conservation practices, such as improvements to water conveyance and application systems, could reduce water diversions in irrigated agriculture. These practices are likely to increase irrigation efficiency, but at the same time reduce return flows which will affect the timing of downstream supplies. In the energy sector, the demand for high quality water can be reduced by conservation measures such as the use of waste or brackish water, dry or hybrid cooling towers in power generation and alternative methods of mining, i.e., water use from insitu mining is ten times less than from surface mining. Domestic water use could also be reduced through water pricing and/or education programs on water conservation in the home.

Other water conservation practices include reduction of water evaporation from reservoirs by film or destratification, i.e., pumping cooler water from below the surface to the surface, and reduction of water consumption by phreatophytes (high water-use plants), along canals and river banks. Methods of phreatophyte control include mechanical and/or chemically preventing plant growth through mowing, spraying or removing the phreatophyte growth. The cost to reduce evaporation losses and phreatophyte water loss is assumed to be paid by the public sector, whereas the adoption of all other water conservation technologies will be borne by either individuals or energy companies in the private sector.

Water Quality Issues

The need to meet numerical standards for salinity (PL 92-500) and to control point and non-point sources of salinity (PL 95-217) is critical to any development of Colorado River Compact Water. The Colorado River Basin Salinity Control Act (PL 93-320) authorized the Secretary of the Interior to construct several projects for the improvement, enhancement and/or protection of water quality in the Colorado River. One of these projects is the Big Sandy River Unit Project to reduce salt loading of the Big Sandy River and the Green River. The Big Sandy River discharges an estimated 180,000 tons of dissolved solids annually into the Green River (U.S. Dept. of the Interior, 1976). The proposed Big Sandy River Unit consists of a number of wells drilled along a 15-mile reach of the river that contributes 110,000 tons of salt annually to the Big Sandy River. Approximately 6,000 acre-feet of water from the wells will be pumped to a lined storage area. The water will then either be sold for use elsewhere or evaporated. The project will reduce salt loading by approximately 80,000 tons of salt per year at an estimated total cost of 32 million dollars.

The Colorado River Basin Salinity Control Act is the major reason for the construction of the Big Sandy River Unit. Without salinity control measures, the salt concentration of the Colorado River will exceed the 879 mg/l criteria established by EPA under PL 92-500.

ANALYTICAL MODEL

A linear program (LP) model was developed at Utah State University to estimate the impacts of agricultural and energy development and the optimal allocation of water given alternative water conservation technologies and salinity management. The LP model was further refined at the University of Wyoming to focus on the impact of alternative public investment in water conservation and salinity control practices needed to achieve EPA salinity regulations in the Green River Basin on the Colorado River. The mathematical model estimated the economic impacts and welfare costs of agricultural growth on energy development, water conservation and salinity management in the Green River Basin for the years 1980 and 2000. The objective function is to maximize agricultural and energy returns less the cost of production, less the annualized cost of public and private investment for water conservation, less salinity control costs and less salinity damage cost caused by exceeding EPA salinity standard. The year 1980 represents a baseline year for production and prices, and provides a basis from which to project the impacts of future agricultural development. For a further discussion of the model see Franklin, Jacobs, and Farris (1983).

The EPA salinity standard at Imperial Dam is first held constant and then relaxed to investigate the impact of salinity control on investment and development, both private and public, within the Green River Basin in Wyoming.

The question addressed was "what are the conditions under which the continued viability of irrigated agriculture in the Green River Basin might be possible with salinity controls and energy development?" "The continued viability of irrigated agriculture" refers to the conditions where irrigated agriculture returns remain at or above current levels in year 2000. It is assumed for planning purposes that in 2000 the net value of agricultural products will increase by approximately 24 percent to 6.2 million over 1980.[1/] This is an associated growth of 1.2 percent per year. The growth in the agricultural sector is analyzed to assess the impacts agricultural growth has in the basin.

The next section discusses impacts with first, a maintained, and second, a growing agricultural base. Conclusions are also presented with regards to public and private investment alternatives to enhance development in southwestern Wyoming.

1/ This implies that prices received will increase faster than prices paid which is a heroic assumption to say the least. Yet, this is one possible method to force the linear program to achieve a growth in the agricultural sector in order to analyze the impacts given agricultural growth in the basin.

MODEL RESULTS, DISCUSSION AND CONCLUSIONS

If the forecasted level of energy growth in the Green River Basin for the year 2000 occurs and the agricultural sector does not expand, salinity and water availability are not constraints to development. No cost savings would result from relaxing the EPA salinity standard. Without growing agricultural use, the amount of water diverted in the Green River Basin alone is not large enough to increase salinity in the Colorado River. The analysis, however, recognizes that development in all four Upper Basin states could affect the quantity and therefore the quality of water at Lee's Ferry. Therefore, an environmental damage charge would be imposed on Wyoming and the other states.

As water use expands with the growth in the two sectors, stream flow is reduced causing an increase in salinity concentration. Increased salinity concentration could result in damage costs being imposed on Wyoming. Since damage costs are greater than net returns to agriculture, agricultural production is reduced to meet salinity standards. The results are given in Table 1 under Initial 2000 Solution. Increased energy production between 1980 and 2000 accounts for the entire increase in net basin returns. Net basin returns are the net agricultural and energy returns less transportation costs out of the basin, private and public conservation costs and any salinity damage cost.

Impacts of Agricultural Growth

The trade-off between increased agricultural profits and the cost in terms of reduced energy production and salinity damage costs are also given in Table 1. Table 1 summarizes returns and costs associated with increased agricultural production given the alternative of relaxing or maintaining the EPA salinity standard. The analysis includes the impacts on net basin income and net energy income as well as public expenditures on evaporation and phreatophyte control measures.

Table 1. Net Returns, Public Expenditures and Damage Cost Associated With Increased Agricultural Development (Thousands of Dollars).

	Initial 1980 Solution	Initial 2000 Solution	With Agricultural Development in 2000: Without Increased Salinity[a/]	With Agricultural Development in 2000: With Increased Salinity[b/]
Net basin returns	347,947.5	537,773.2	242,294.9	537,580.8
Net ag returns	5,000.7	4,760.4	6,200.0	6,200.0
Net energy returns[c/]	343,002.7	533,008.9	238,704.4	533,008.9
Public investment	12.1	12.1	2,612.1	77.1
Damage cost	0	0	0	1,566.9[d/]

a/ Increased salinity concentrations downstream is not increased over the EPA standard.

b/ The salinity concentration downstream is increased by 1.2 percent over the EPA standard.

c/ Net energy returns include industrial growth that is projected to occur within the basin. Thus, it is not entirely associated with energy growth.

d/ The damage cost is the direct result of the increased salinity concentration from increased agricultural and energy production.

If irrigated agriculture expands by 24 percent and the salinity standard is relaxed, net energy returns are not affected. Public investment in reservoir evaporation suppression and phreatophyte control is minimal of ($77,100). Increased salinity concentration over the EPA level of 879 mg/l (1.2 percent) causes damages of $1,566,900. The increased agricultural returns of $1.2 million over 1980 are offset by the damages of $1.57 million; thus, the net cost of this "scenario" is a $200,000 loss of net basin returns when compared to the Initial 2000 Solution.

Alternatively, if the EPA salinity standard of 879 mg/l were maintained, then increased net returns to agriculture of 24 percent ($1.4 million) would result in net energy returns being reduced by 55 percent ($294 million) and public investment increases by 215 percent ($2.6 million). The total public investment includes an annualized cost (over 30 years) of $2.4 million for the construction and implementation of the Big Sandy River Salinity Control Unit to reduce salt loading of the Green River. The remaining investment of $212,007 in evaporation and phreatophyte control salvages approximately 8,812 acre-feet of water (an average cost of $24.07 per acre-foot). The additional 8,800 acre-feet of water is used as a method to increase surface flow thereby decreasing the salinity concentration by dilution. The net cost of increasing net agricultural returns by $1.4 million is $295.5 million. This net cost is almost entirely borne by the energy sector. Thus, if agriculture has the first right to water on the Green River drainage, development of energy resources may be severely restricted.

The question that must be analyzed is, "what is the appropriate policy?" If the EPA salinity standard must be maintained to protect users in the Lower Colorado River Basin states, is a cost of $295 million in reduced returns from energy development a reasonable policy choice to enable agricultural production and returns to increase by $1.4 million? The appropriate answer depends upon the position state policy makers wish to take with respect to agricultural versus energy production. Table 1 shows that with no agricultural growth, returns to agricultural declined approximately $240,000 from 1980 to 2000, a five percent decrease in the agricultural sector. However, overall basin returns increased due to energy sector growth without increasing salinity downstream.

The effects of a smaller eight percent growth assumption were also analyzed. As net agricultural income increases by $400,000 and the salinity standard is maintained, net energy income is not affected, but basin wide net returns are reduced by $727,791 or less than 0.2 percent. Total public investment is increased by $1,367,000 for phreatophyte control and construction of a smaller scale Big Sandy River Salinity Control Unit ($1.2 million or approximately one-half size of the total unit). Thus, even a small annual growth of 0.4 percent in net agricultural returns over 20 years will result in a net cost of over $727,000 in 2000. Again, a policy choice of agricultural growth versus increased public costs borne by the state or federal government must be made.

With increased irrigation, the increase in agricultural returns is less than the cost imposed on the state because of salinity damages. Any decrease in energy production will result in a loss of mineral tax funds, which has not been estimated. Thus, the taxing capacity of the state and other states indirectly will be reduced.

Concluding Remarks

The results of the model suggest that if water rights were easily transferable, development of energy resources along with their municipal impacts could be accomplished with limited public investment, loss in net farm income or increases in salinity. Wyoming will not completely "use" its full entitlement to Colorado River water. If, however, water rights are not freely transferable, as is the case under Wyoming water law, and agricultural returns increase by 24 percent (1.2 million), the net cost to the state is estimated to be a minimum of $1.5 million.

Salinity concentration is a major constraint to development in the Upper Colorado River Basin. If agricultural growth is to take place, without violating salinity standards, public investment must take place and large potential returns from energy development must be foregone. Without public investment and water transfer to the energy sector, the implications could be even larger because of reduced development of energy resources.

As salinity concentration is allowed to increase downstream over EPA standards, the imposition of additional costs are borne by Wyoming thus decreasing the opportunity to increase basinwide profits, e.g., agricultural profits are increased by $1.2 million, but salinity damages cost $1.5 million. Irrigators will not be willing to pay for the cost of increased salinity. The public investment expenditures by the state to control salinity is a concern that has to be considered.

As the case study illustrates, agricultural development could severely limit energy development and increase public expenditures if a government regulation on salinity is strictly enforced. However, the relaxation of the salinity standard could possibly allow for an expanded energy and agricultural sector in Wyoming, yet the net cost is the imposition of a damage cost and increased salinity damages to downstream users. The Lower Colorado River Basin states benefit greatly by the enforcement of the salinity regulation by reduced cost of maintenance and replacement of "damaged" structures. The salinity control policy is ultimately up to the federal government, yet the costs in terms of lost revenue versus damage costs are imposed on private individuals, firms and the states involved. This illustrates the cost imposed on one state and the salinity impact on all states of the Colorado River Basin. However, as development occurs in all states, salinity becomes even more of a problem in terms of increased damages downstream, thus, this analysis is applicable in principle to all Upper Basin states.

REFERENCES

Franklin, D.R., J.J. Jacobs and Paul J. Farris. "Water Resource Development Impacts in the Green River Drainage of Wyoming." Wyoming Agricultural Experiment Station. Research Journal 189, University of Wyoming, Laramie, 1983.

Hyatt, Milton Leon. Analog Computer Model of the Hydrologic and Salinity Flow Systems within the Upper Colorado River Basin. Unpublished Ph.D. Dissertation, Utah State University, Logan, UT, 1970.

Narayanan, Rangesan, Sumol Padungchai, and A. Bruce Bishop. "An Economic Evaluation of the Salinity Impacts from Energy Development: The Case of the Upper Colorado River Basin." Water Resources Planning Series. UWRL/P-79/07. Utah Water Research Laboratory, Logan, December 1979.

Padungchai, Sumol. "An Economic Analysis of Water Quality Improvement Policies: The Optimal Combination of Salinity Control Techniques. Ph.D. Dissertation, Utah State University, Logan, 1980.

U.S. Department of the Interior. Report on Water for Energy in the Upper Colorado River Basin. Water for Energy Management Team. Washington, D.C., July 1974.

U.S. Department of the Interior. Colorado River Water Quality Improvement Program. Draft Environmental Impact Statement. Bureau of Reclamation. Washington, D.C., March 1976.

U.S. Water Resources Council. Upper Colorado Region Comprehensive Framework Study. Prepared by the Upper Colorado Region State-Federal Interagency Group/Pacific Southwest Interagency Committee, 1971.

Upper Colorado River Commission. Thirtieth Annual Report. Salt Lake City, Utah, September 1978.

Wyoming State Engineer. State of Wyoming. Working Paper Green River Basin Wyoming, Type IV Study. "The Agricultural Base," February 1977a.

Wyoming State Engineer. State of Wyoming. Working Paper Green River Basin Wyoming, Type IV Study. "Base Resource," March 1977b.